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(54) CODE SIGNAL RECEIVER CIRCUITS

(71) I, THE SECRETARY OF STATE FOR DEFENCE, London, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to code signal receiver circuits and in particular to such circuits for the reception and detection of signals phase-modulated in accordance with a predetermined sequence of code signals at a transmitter.

Signals transmitted by a transmitter may be coded, that is to say modulated in a predetermined way known both to the sender and receiver, for a variety of reasons. In a telecommunications application the signals may be coded to prevent third persons from understanding the information conveyed by the signals. In a radar application the signals may be coded to give the signals a characteristic varying with time which can be used at the receiver to determine position information of a target. In all applications the signals may be coded to give the receiver an enhanced detection capability when the signals are accompanied by unwanted noise.

It is an object of the present invention to provide receiver circuits which may receive and detect signals phase-modulated in accordance with a predetermined sequence of code signals at a transmitter.

According to the present invention receiver apparatus for detecting the occurrence of a part of a predetermined cyclic code sequence in received digital signals encoded according to a prescribed phase-shift-keying code, includes a decoder circuit for applying to the received signals a sequence of phase-shifts complementary to the phase-shifts used to encode the said part of the predetermined cyclic code sequence by the said prescribed phase-shift-keying code.

In a preferred form of the apparatus, for the detection of signals bi-phase modulated by a predetermined code sequence of binary signals, the decoding means may be a conventional balanced-mixer or ring modulator circuit used so as to function as a bi-phase modulator.

In radar applications the output of the decoding means may be connected to signal mixing means for mixing signals at the output of the decoding means with the same signals delayed by an integral multiple of the predetermined rate. The signal mixing means may be a phase-detector circuit having one input connected directly to the output of the decoding means and a further input also connected to the output of the decoding means but via a delay line giving a delay equal to an integral multiple of the predetermined rate. The delay line may be a surface-wave acoustic delay line. In some radar applications for example a radar proximity fuze, the output of the phase-detector circuit may be connected via a low-pass filter and an integration circuit to threshold circuit means, so that when the phase-shifts on the received signal are cancelled by correctly synchronised complementary phase-shifts the threshold detector will give an output which can trigger a fuze or indicate detection. In these applications the received signal may comprise a carrier-wave phase-shifted by either 0° or 180° corresponding to 1-signals and 0-signals of a binary code sequence respectively. Each bit of the binary code sequence is of the predetermined bit duration.

In radar applications of course, where the transmitter and receiver are co-located, the same code generator circuit which provides for the coding of the transmitted pulses may be used to provide the complementary phase shifts to be applied to the decoding means in the receiver circuit. A suitable delay inserted between the code generator and the decoding means will ensure that detection is achieved at a particular range.

In telecommunications applications the received signal may be a phase-modulated signal to which the coded sequence of phase shifts has been applied additionally. Only when the complementary phase-shifts applied

to the decoding means are in synchronism with the coded sequence will the required phase modulated signal be ascertained. Thus the invention provides means for transmitting data, for example speech, in a secure manner, decipherable only by thise who know the code in use and apply the correct complementary phase shifts to the decoding means. Further, the code may be of any convenient repeating length and the phase shifts corresponding to one and zero signals in the code can be chosen by the operators: a combination providing a formidable deciphering problem.

Embodiments of the invention will now be described by way of example only and with reference to the drawings accompanying the provisional specification of which,

Figure 1 is a block schematic circuit diagram of a radar proximity fuse receiver circuit, and

Figure 2 is an alternative form of the receiver circuit shown in Figure 1.

In Figure 1 an intermediate frequency (IF) amplifier 1 is connected to receive signals from a receiving aerial (not shown), and to apply the IF signals to a first input of a conventional balanced mixer circuit 2. The code generator 3 has an output connected via a suitable range-delay line circuit 6 to a second input of the balanced mixer circuit 2. The output of the code generator 3 is also connected to transmitter circuits (not shown) for example, to bi-phase pulse modulation transmitter apparatus as described in the applicant's co-pending Patent Application No. 25344/72 (Serial No. 1,432,541). The output of the balanced mixer circuit 2 is connected to one input of a phase detector circuit 8 and also via a delay line 7 to another input of the phase detector circuit 8. The output of the phase detector circuit 8 is connected via a low pass filter 9 and integrator circuit 10 and a threshold circuit 11 to trigger circuit (not shown) which activate the fuze (not shown) of the weapon (not shown) in which the radar is located.

In operation, the transmitter circuits (not shown) transmit a regular series of microwave pulses of constant frequency but of phase determined by a random or pseudo-random binary code generated by the code generator 3. Apparatus for coding the transmitted signals with either 0 or 180° phase shifts has been described in the applicant's co-pending Application No. 25344/72 (Serial No. 1,532,541). Each transmitted pulse is followed by a period of non-transmission during which the pulses returning from the target may be received. The pulses received by the receiver aerial (not shown) are applied to the intermediate frequency amplifier 1. Although the output of the IF amplifier 1 is a series of pulses of a different frequency to those transmitted, nevertheless the binary coded phase information is maintained and applied to the first input of the balanced mixer circuit 2. The output of the code generator 3 is delayed in the delay line 6 and applied to the second input port of the balanced mixer circuit 2. The transmitted pulses received by the receiver aerial (not shown) will have suffered a delay depending on the range of the target from which they are reflected. The time delay due to the delay line 6 is chosen to equal the propagation delay over the transmitter-target-receiver path when the range to the target reaches a value at which it is desired to activate the fuze (not shown). One-signals produced by the code generator 3 causes a positive direct current pulse to be applied to the second input of the balanced mixer circuit 2 and zero-signals cause a negative direct current pulse to be applied thereto. A positive pulse applied to the second input of the balanced mixer circuit 2 changes the phase of the signals at its output with respect to those at its first input by 180°. A negative pulse applied to the second input of the balanced mixer circuit 2 leaves the signals appearing at its output unchanged with respect to those at its first input. When the aforesaid propagation delay equals the delay applied to the code generator signals by the delay line 6 the output of the balanced mixer circuit 2 will be a series of pulses of constant phase at the IF frequency. The phase detector 8 compares the phase of each of the output pulses of the balanced mixer circuit 2 with that of the preceding pulse since the delay 7 is arranged to produce a 1-bit delay The output of the phase detector circuit 8 will be a direct voltage of a predetermined level and polarity when the two inputs to it are out of phase, and will be a direct voltage but of opposite polarity whenever they are in phase. Because the input signals to the phase-detector circuit 8 are pulses of signals at the IF frequency its output will also consist of pulses of one polarity or the other. These pulses from the phase detector circuit 8 are integrated in the integrator circuit 9. Whenever successive pulses at the input to the integrator circuit 9 are of randomly varying polarity, corresponding to a target outside the chosen range, the output of the integrator circuit 9 will be a signal fluctuating randomly in voltage level. However when successive pulses are of the same polarity, corresponding to a target at the chosen range, the output of the integrator circuit will be a signal steadily rising in voltage level. In either case, because pulses are applied to the input of the integrator circuit 9 its output signal will change level in discrete steps. The low-pass filter 10 smoothes out these steps and also rejects fluctuating signals of the type produced by the integrator circuit 5 for an out of range target. When the output signal

from the low-pass filter 10 reaches a predetermined magnitude, as it eventually will if the target is at the chosen range, the threshold circuit 11 produces an output which is fed to trigger circuits (not shown) to initiate the fuze and explode the weapon to which the device is attached.

In Figure 2 an alternative form of the receiver circuit shown in Figure 1 is shown which makes use of surface-wave acoustic delay lines to perform a pre-detection integration. The circuit shown in Figure 2 is found to have improved signal-to-noise characteristics and can detect the desired signals even when these are several orders below the level of the noise present in the receiver circuits. Where elements of the receiver circuit in Figure 2 are identical to those shown in Figure 1 common reference numbers have been used. An IF amplifier 1 is connected to the first input of a balanced mixer circuit 2, the second input of which is connected to the code generator circuits as shown in Figure 1. The output of the balanced mixer circuit 2 in this case is connected to the fingers of two acoustic surface-wave transducers 15 and 16 mounted on opposite ends of a surface-wave acoustic delay line 12. A further transducer 17 is positioned between the transducers 15 and 16 so that signals travelling from the transducer 15 to the transducer 17 suffer a 1-bit delay and signals travelling from the transducer 16 to the transducer 17 suffer a 2-bit delay. The output finger of the transduced 17 is connected in exactly the same way to further transducers of another surface-wave acoustic delay line 13. A number of such devices are connected in series; for convenience only three devices 12, 13 and 14 have been shown here. The output of the last device, in this case 14, is connected via an integrator circuit 10 to a trigger circuit 11. The output of trigger circuit 11 is connected to an alarm or fuze (not shown).

In operation, as before, microwave pulses phase-modulated by the code generator 3 (Figure 1) are transmitted towards the target (not shown) and after reflection from the target are received by the receiver aerial (not shown) and applied to the normal IF circuits of the receiver. The output of the IF amplifier 1 is applied to the first input of the balanced mixer circuit 2, also as before, and the delayed binary code signals from the code generator 3 are applied to its second input. When the target is at the range corresponding to the delay 6 of Figure 1, the output of the balanced mixer circuit will be a series of pulses of IF frequency signals, coherent in phase, because the received coded pulses and the reference coded pulses will be identical. These pulses are applied to the surface wave acoustic delay line 12. The transducer 17, because of its position with respect to the transducers 15 and 16, will in effect compare the phases of successive pulses. When each pulse and its preceding pulses are in phase they will arrive at the transducer 17 in phase and the output of the transducer 17 will be an enhanced pulse of signals at the IF frequency. Noise signals in the IF amplifier output will generally have unstable or random phase and hence noise signals from the transducers 15 and 16 will be unlikely to arrive at the transducer 17 in phase with each other. It has been found that the device 12 gives an improvement in signal to noise ratio of the order of 3 dB. The stages 13 and 14 and other stages which may be added give further, but successively smaller, improvements in signal-to-noise ratio. The overall effect however is that a signal which is received and is initially of a level well below the prevailing noise signal level can be recovered by a series of devices such as 12, 13 and 14 in Figure 2. The output of the final surface-wave acoustic delay line device, in this case 14, is a series of pulses of IF freqeuncy signals of coherent phase when the target is at the range specified by the delay 6. As before, the phase detector 8 compares the phase of each output pulse of the balanced mixer circuit 2 (but this time preprocessed by the surface-wave acoustic delay lines 12, 13 and 14) with that of the preceding pulse which is delayed by the delay line 7. The output pulses from the phase detector 8 are integrated in the integrator circuit 9 the output of which is smoothed by the low-pass filter 10 and, when the output of the low-pass filter 10 reaches a predetermined level, trigger circuits 11 are operated which activate the fuze of the device or sound an alarm as appropriate.

Many modifications to the above circuits and other applications of the above circuits will now suggest themselves to those skilled in the art. For example, in a telecommunications application the transmitted signals may be phase-modulated such that the magnitude of the phase perturbation is directly proportional to the amplitude of a signal, for example speech, to be transmitted. Apparatus for doing this has been described in applicant's co-pending Application 25344/72 (Serial No. 1,432,541). The code signals from the code generator circuit 3 may then be applied to superimpose a further bi-phase modulation on this signal by a code modulator in the transmitter which may correspondingly change the electrical or acoustic path length of part of the signal path by plus or minus a half-bit length. At the receiver the phase-modulated signal is restored for detection by first removing the coded sequence of bi-phase shifts with apparatus as described hereinabove. Only persons knowing the code in use would be able to restore the phase-modulated signal correctly. In this

case the receiver would be equipped with an independent code generator producing an identcial code to that known to exist at the transmitter. The delay 6 would then be set to correspond to the known range between transmitter or receiver or alternatively the output of the phase detector circuit 8 could be used to cotnrol the delay 6 so that the correct decoding is performed by the mixer 2 in those cases where the range between the transmitter and receiver is either initially unknown or is changing. In this telecommunication application a parallel output of the balanced mixed circuit 2 would be the required phase-modulated signals which could then be fed to detector circuits as described in applicant's copending Application 25344/72 (Serial No. 1,432,541).

WHAT I CLAIM IS:—

1. Receiver apparatus for detecting the occurence of part of a predetermined cyclic code sequence in received digital signals encoded according to a prescribed phase-shift-keying code, including a decoder circuit for applying to the received signal a sequence of phase-shifts complementary to the phase-shifts used to encode the said part of the predetermined cyclic code sequence by the said prescribed phase-shift-keying code.

2. Receiver apparatus for detecting the occurrence of part of a predetermined pseudo-random binary code sequence in received signals encoded according to a prescribed phase-shift-keying code, including a decoder circuit comprising a balanced mixer circuit connected to phase-modulate the received signals by delayd code signals derived from the predetermined pseudo-random binary sequence through a signal delaying means so that it applies phase-shifts to the received signals which are complementary to the phase-shifts which would be used to encode the delayed code signals by the prescribed phase-shift-keying code.

3. Receiver apparatus as claimed in claim 1 or claim 2 and including a signal mixing means connected to receive output signals from the decoder circuit via two signal paths such that signals received through one of the paths are delayed relative to the signals received through the other path by an integral multiple of the digit interval of the received signals.

4. Receiver apparatus as claimed in claim 3 wherein the signal mixing means is a phase-sensitive detector circuit.

5. Receiver apparatus as claimed in claim 3 and having a surface acoustic wave delay line in one of the said signal paths.

6. Receiver apparatus as claimed in claim 3, wherein the signal mixing means comprises at least one surface-wave acoustic delay line having first, second and third electro-acoustic transducers mounted thereon, the difference in the distance between the first and the third and the second and the third transducers corresponding to an integral multiple of the predetermined digit-signal rate for acoustic signals propagated on the delay line at the acoustic surface-wave velocity characteristic of the material of the delay line, wherein the first and second electro-acoustic transducers have electro-signal inputs which are connected together and to an output of the decoding means, or, where there is more than one such delay line, to an eletcric signal output of the third electro-acoustic transducer of the preceding delay line, and wherein the electric signal output of the third electro-acoustic transducer of the last delay line in the chain is connected to one input of a phase detector circuit and via a delay line giving a delay equal to an integral multiple of the predetermined digit rate to a second input of a phase detector circuit.

7. Receiver apparatus as claimed in claim 4, claim 5 or claim 6 and wherein the output of the phase detector circuit is connected to a threshold circuit via an integration circuit and low-pass filter circuit connected in series.

8. Receiver apparatus as claimed in any one of the preceding claims and including a code generator for producing a sequence of signals representing the desired sequence of phase-shifts and connected to the decoding means via a delay circuit.

9. Receiver apparatus according to claim 1 substantially as hereinbefore described with reference to Fig. 1 or Fig. 2 of the drawings accompanying the provisional specification.

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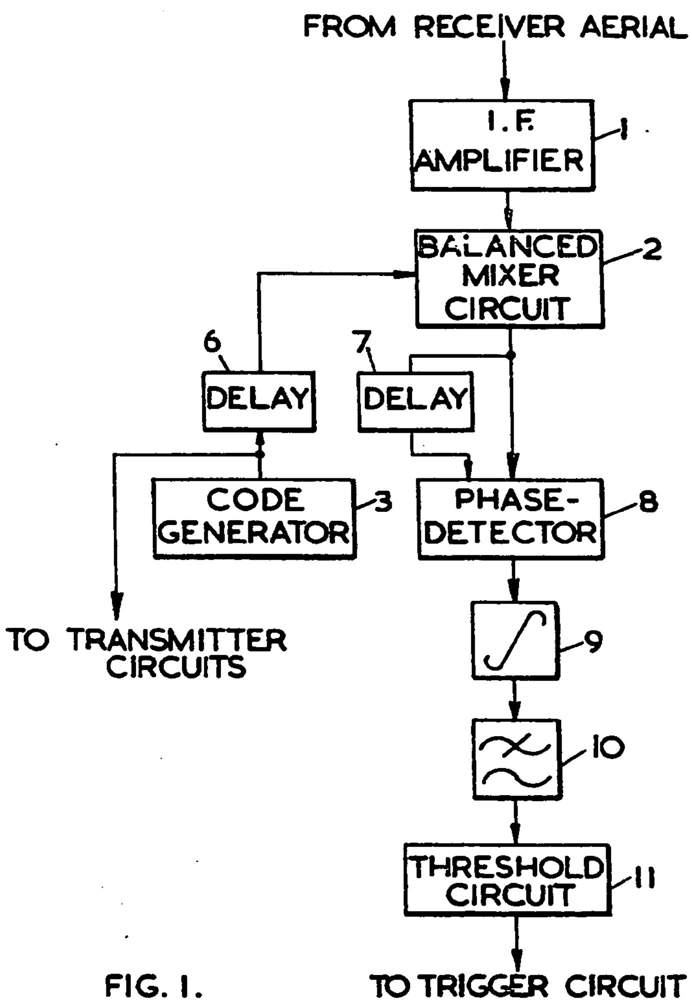
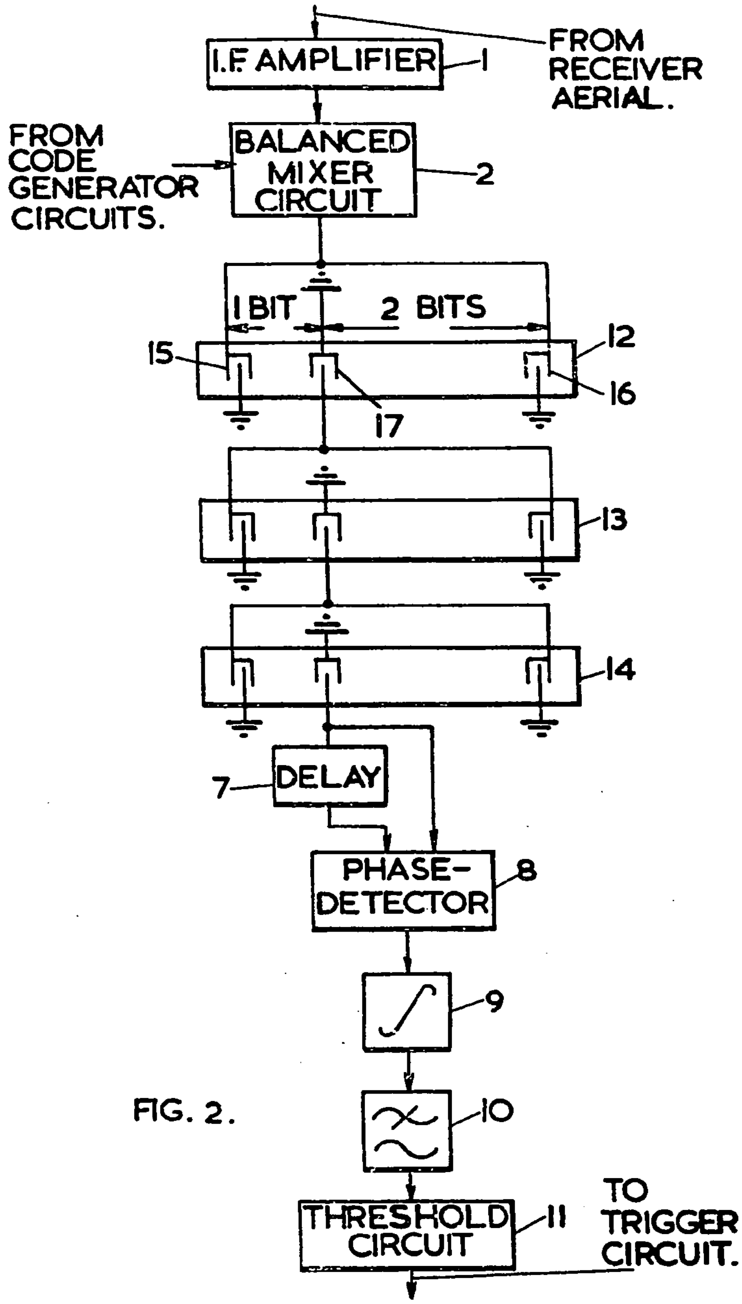

FROM RECEIVER AERIAL
I.F. AMPLIFIER
1
BALANCED MIXER CIRCUIT
2
6
DELAY
7
DELAY
CODE GENERATOR
3
PHASE-DETECTOR
8
TO TRANSMITTER CIRCUITS
9
10
THRESHOLD CIRCUIT
11
TO TRIGGER CIRCUIT

FIG. 1.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PHASE-DETECTOR
8
9
10
THRESHOLD CIRCUIT
11
TO TRIGGER CIRCUIT.

FIG. 2.